Executive Summary

The primary purpose of this technical memorandum is to evaluate and summarize the geologic storage potential of carbon dioxide (CO_2) within the Laramide basins of Wyoming. The Laramide basins were formed during a major geologic event known as the Laramide orogeny, approximately 80–55 million years ago. The Laramide basins assessed for this study include the Greater Green River, Wind River, Bighorn, Powder River, Hanna, and Denver basins.

Carbon dioxide is a greenhouse gas that is released through many natural and anthropogenic processes, including the burning of fossil fuels. In Wyoming, the bulk of electricity-generating plants burn the fossil fuel coal, which is primarily extracted from the Powder River Basin and Greater Green River Basin. Capturing CO_2 emissions from these plants for permanent underground storage in geologic formations offers an environmental as well as potential economic incentive; CO_2 would be prevented from entering the atmosphere and Wyoming would provide low-emissions coal-sourced energy to much of the country.

In fact, Wyoming was the first in the nation to establish regulations for the storage of CO_2. In 2008, the state Legislature passed two laws establishing underground storage rights and a framework for state regulation of carbon storage.

Effective geologic storage of CO_2 requires several site-specific attributes. These attributes include a proper trap (generally structural or stratigraphic), a porous and permeable sequestration zone, an overlying competent seal with very low permeability, under-pressured to normally pressured reservoirs, and the potential to displace significant amounts of saline reservoir fluids. Ideally, subsurface sequestration depths should be greater than 914 m (3,000 feet) to maintain CO_2 in a supercritical state and less than 3,962 m (13,000 feet) to correspond to CO_2-pipeline pressures that would not require significant additional compression at the surface before injection. Within a single basin, there can be several potential storage locations and formations.

This assessment evaluates four distinct methods of CO_2 storage in each Laramide basin. The first method is storage in deep saline aquifers. Saline aquifers, for the purpose of CO_2 storage, are characterized as aquifers with total dissolved solid concentrations greater than 10,000 mg/L, well above the 500 mg/L national standards for safe drinking water. Saline aquifer storage assessment generally focuses on a specific geologic formation, frequently encompassing a large area. This assessment of the Laramide basins follows the guidelines specified in the "CO_2 Atlas III," published by the National Energy Technology Laboratory in 2010. This assessment is limited by the generality of the guidelines, as well as the structure of the Laramide basins. As implied by the term, "basins" have a bowl-shaped geometry, with the deepest part generally near the center. This geometry is not conducive to large-scale and permanent CO_2 storage, as CO_2 will over time migrate up-dip toward the basin margins and potentially escape. The rate of migration varies for each locality, and may be slow enough to consider CO_2 storage a relatively long term proposition (decades to thousands of years), but likely would not be a permanent solution.

The second assessment method is for storage in currently producing oil and gas reservoirs once the reservoirs have reached their economic limit. Hydrocarbon reservoirs have effective traps with proven seals, and thus represent a high potential for effectively storing CO_2 in a more permanent manner. This study determines the largest, or most productive, fields in each of the basins, and assumes these fields have the largest available pore space for storing CO_2. In many cases, the fields are currently and actively producing hydrocarbons. These fields are not depleted, and it is not the intent of this study to imply that CO_2 storage should occur in these fields at this time. Rather, these are potential future reservoirs for CO_2 storage; geologic CO_2 storage will not be a viable option until hydrocarbon recovery in these fields is no longer economically feasible. This method determines the mass of CO_2 that can be stored in these hydrocarbon fields from past production history, and does not account for additional pore space created through future production. This assessment is valid for production reported to the Wyoming Oil and Gas Conservation Commission through 2011, and incorporates assumptions that would need to be independently verified, on a case-by-case basis, for CO_2 storage in a specific reservoir in a specific field.

The third method of assessment is CO_2 storage as a consequence of enhanced oil recovery, or EOR. Enhanced oil recovery has been an active practice by the petroleum industry in Wyoming since the mid-1980s as a tertiary form of oil recovery. Carbon dioxide is injected into a declining oil reservoir to increase recovery of the oil remaining in the reservoir. Once EOR has been completed and the oil has been removed, the reservoir could become a trap for the CO_2 used in the project. This assessment reviews the CO_2-EOR studies by the Wyoming Enhanced Oil Recovery Institute and summarizes their predicted CO_2 demand in specific reservoirs throughout the state.

The final assessment includes CO_2 storage through enhanced coalbed natural gas (methane) recovery, or CO_2-ECBM. Storage through CO_2-ECBM takes advantage of the preferential adsorbtion of CO_2 to coal at the expense of methane gas; injecting CO_2 into coalbed natural gas reservoirs increases methane production. The significant coalbed natural gas fields in the Greater Green River, Wind River, Powder River, and Hanna basins are potential targets for future CO_2-ECBM, and the theoretical mass of CO_2 that can be stored in coal beds within these basins is summarized in this assessment from work reported in the literature.

Of the assessed methods, CO_2-EOR appears to have the greatest near-term potential to geologically and economically store CO_2 in Wyoming. This is a proven method of storage and in many cases the pipeline infrastructure is already in place. However, the pipeline infrastructure must be expanded before large-scale CO_2-EOR in the highest-priority locations, including the Powder River, Bighorn, and Greater Green River basins, can take place. Only future economics, associated with a long term increase in oil price, will support and drive this development. There are currently six CO_2-EOR projects in Wyoming. Assuming that CO_2 demand is equal to storage, this assessment finds that Wyoming's candidate reservoirs for CO_2-EOR could potentially store 30 years of CO_2 emissions from Wyoming electricity-generating power plants at 2011 emission levels.

Saline aquifers have the potential to store the largest volumes of CO_2 in one location, minimizing the need for extensive pipeline development. The electricity-generating plants with the highest CO_2 emissions reside in the Powder River and Greater Green River basins. This CO_2 storage assessment finds that both basins can theoretically store anthropogenic CO_2 produced from these plants for many years, yet only the Greater Green River Basin has the large geologic traps required for economic longer-term CO_2 storage. These traps include the Rock Springs uplift, Moxa arch, and possibly the Wamsutter and Cherokee Ridge arches. Further evaluation and characterization of these traps is essential to determine the extent of the obstacles associated with CO_2 storage in these locations. Possible and likely obstacles include extreme formation depths, inadequate porosity and permeability, fractured reservoirs, faulted and compartmentalized reservoirs, aquifer salinity less than the required minimum concentration, and significant saline water production at the surface that will require an appropriate disposal solution, to name a few. The Carbon Management Institute at the University of Wyoming is currently evaluating the Rock Springs uplift and Moxa arch, which appear to be the highest potential locations for CO_2 storage in deep saline aquifers in Wyoming.

Carbon dioxide storage in existing hydrocarbon reservoirs has potential, yet this storage method is less attractive because the volume of CO_2 that can be held in each individual field is small. This assessment finds that the largest fields in the Laramide basins can likely store no more than 15 years of CO_2 emissions from Wyoming electricity-generating power plants at 2011 emission levels. Economic and efficient CO_2 storage will require tens of years of storage of CO_2 emissions from power plants.

If CO_2 storage through CO_2-ECBM were to occur in Wyoming, it would probably first occur in the Powder River Basin, which hosts large coalbed natural gas fields with significant CO_2 storage capacity. The CO_2 storage capacity of coalbed natural gas fields of the Greater Green River Basin follows closely on the heels of the Powder River Basin, and may also be an ideal location for CO_2-ECBM due to its proximity to the natural CO_2 source in western Wyoming. However, CO_2-ECBM is not currently employed anywhere in Wyoming due to a lack of economic viability at current and near-term methane prices. There is potential for this technology and only time will tell if it is economically feasible and utilized. This approach only represents a permanent storage solution if the coal is never mined.

Wyoming is currently in a challenged position regarding long-term geologic CO_2 storage. Technically, CO_2 storage is feasible, by any of the aforementioned methods. The hydrocarbon industry routinely injects and/or stores water, natural gas, and CO_2 in subsurface reservoirs. Although this technology must be slightly modified to accommodate CO_2 storage, the technology is not the limiting factor. Instead, the primary issues are economics and CO_2 source. Estimates for the cost of geologic CO_2 storage vary widely, yet investment, operating, and monitoring costs can be significant and can only be offset by potential economic incentives, such as additional state and federal subsidies, or natural changes in market conditions. Already greenhouse gas emissions from fossil fuel power plants are becoming more regulated, as seen in the proposed U.S. Environmental Protection Agency rule regarding CO_2 emission standards for new power plants (EPA-HQ-OAR-2011-0660, March 27, 2012; delayed April 13, 2013).

Short and long-term sources of CO_2 in Wyoming also remain a significant issue. The only existing utilized source is geologic; CO_2 is produced from subsurface wells, as a byproduct of helium and methane extraction, and distributed via pipelines. This practice, although economic for the purpose of enhancing oil recovery through CO_2-EOR, is in part contradictory to the fundamental goal of geologic CO_2 storage which is to reduce greenhouse gas emissions. Since CO_2 storage is a side effect and not the primary goal of CO_2-EOR (which is economic oil recovery), current CO_2-EOR projects do not use anthropogenic CO_2. The capture and use of CO_2 from power plant emissions would likely be more costly than the current use of CO_2 from underground reservoirs. However, the basic CO_2 delivery pipelines are in place. Adding to or replacing the CO_2 source in these pipelines from geologic to anthropogenic remains a distinct yet potentially economically challenged possibility and would allow for CO_2-EOR to be the first successful storage of anthropogenic CO_2 in Wyoming.

The issues and challenges raised by this study should be addressed in detail before proceeding with long-term geologic CO_2 storage in Wyoming. These issues and challenges are significant, yet so is the potential CO_2 storage resource of Wyoming's basins. If these issues and challenges can be economically alleviated, the future ability to capture and store power plant emissions could place Wyoming at the forefront of sustainable electric power generation.